THE ROLE OF THE BLOOD ADRENALIN AND OF CARDIOSCLEROSIS IN THE MECHANISM OF PAROXISMAL TACHYCARDIA

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Attacks of paroxysmal tachycardia are often observed in persons with heart disease, cardiosclerosis and other diseases of the cardiovascular system. This type of attack is known to be based on the appearance of a hypertonic source of excitation in the myocardium, which temporarily becomes the pacemaker of the cardiac rhythm. However, the factors which lead to the formation of the focus of heterotopic excitation, convert it into the pacemaker of the cardiac rhythm, and thereby provoke attacks of paroxysmal tachycardia, are in many respects unexplained.

In order to study this problem further, in long term experiments we produced attacks of paroxysmal tachycardia in dogs with experimental heart lesions.

EXPERIMENTAL METHOD

A graded and permanent experimental lesion was created by constriction of the aorta immediately above the valve. Under these circumstances the cross section of the aortic orifice was reduced to one quarter its original size. The ligature producing stenosis of the aorta was passed through a polyvinyl chloride tube and did not damage the wall of the aorta. Four dogs with compensated aortic stenosis were kept under observation for 12-18 months after operation.

Before and after the creation of the heart lesion in these animals, the changes in the cardiac activity arising after the intravenous injection of adrenalin (0.5 ml of a 1: 1000 solution) were recorded electrocardiographically. A rise in the arterial pressure is known to develop as the result of the direct vasoconstrictor effect of adrenalin. The action of the increased pressure on the pressure receptors in the aortic and carotid sinus zones leads to intensification of the signals from these receptors, to excitation of the vagus nerve center and to reflex bradycardia. After division of the vagus nerves, the intravenous injection of adrenalin in our experiments, as in those by other research workers [1], did not cause bradycardia.

The reflex bradycardia caused by adrenalin was expressed as a fall in the heart rate from 100-72 to 60-42 beats per minute; it lasted 2-3 minutes and was replaced by tachycardia. On this background of bradycardia, attacks of paroxysmal tachycardia regularly developed in the dogs with the heart lesion, and these attacks formed the object of study in the present research.

EXPERIMENTAL RESULTS

Against the background of adrenalin-induced bradycardia in the dogs, extrasystoles and attacks of paroxysmal tachycardia were observed. In evaluating these phenomena, it must first of all be emphasized that extrasystoles were present during bradycardia not only in the dogs with the heart lesion, but also in the same

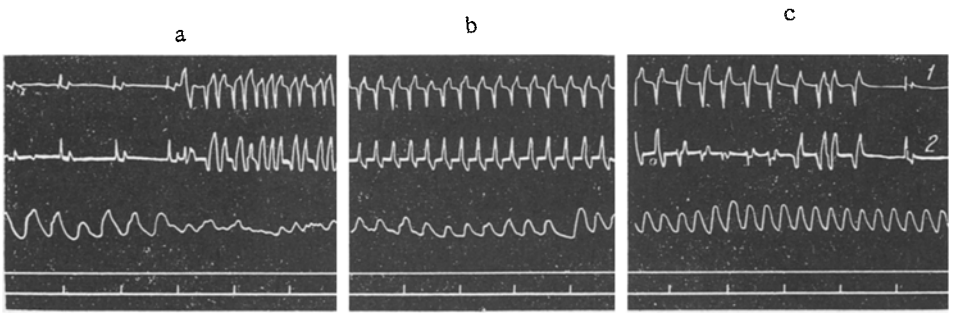

Fig. 1. Electrocardiogram and pneumogram at the beginning (a), in the middle (b) and at the end (c) of an attack of paroxysmal tachycardia in a dog. 1) ECG, lead I; 2) ECG, lead III.

animals before operation, but attacks of paroxysmal tachycardia were observed only in animals with a heart lesion and were never found in normal animals.

Extrasystoles developed in normal animals in roughly half the experiments, and was expressed as the appearance of single and sometimes of groups of left ventricular or right ventricular extrasystoles. After the creation of a heart lesion, the extrasystoles on the background of the adrenalin bradycardia were sharply intensified; they were observed in all the experiments, occurring in the 1-4 months immediately after production of the lesion, and were expressed as groups of right ventricular and left ventricular extrasystoles, alternating with each other. At times the extrasystolic contractions followed one after the other, and then it was possible to speak of a ventricular rhythm. The electrocardiogram has a mixed appearance, for on it right and left ventricular extrasystoles alternated with normal cardiac cycles.

The appearance of heterotopic sources of excitation in the myocardium and the development of extrasystoles are evidently due to the fact that in the first phase of its action adrenalin had a dual effect on the heart.

Reflexly, and by its action on the vagus nerve center, adrenalin causes vagal inhibition of the automatism of the sinus node, and thus makes possible the emergence of potential sources of heterotopic excitation. On the other hand, the direct action of adrenalin on the heart is not only positively chronotropic, but also consists of increasing the excitation of the myocardium. Under these circumstances the influence of the vagus nerve extends to a far greater degree to the sinus node than to the myocardial cells of the ventricles, whereas the direct action of adrenalin is addressed equally to both components of the system. As a result, when adrenalin is present in the blood, a situation is unfolded in which the normal pacemaker of the cardiac rhythm is inhibited and the potential sources of cardiac automatism pass into a state of excitation — extrasystoles are produced. After the reflex inhibition of the sinus node disappears and the adrenalin bradycardia is replaced by tachycardia (second phase of the action of adrenalin), the extrasystoles quickly disappear.

Attacks of paroxysmal tachycardia of left ventricular origin were observed in all four dogs under investigation for a long time. At first the attacks arose $3\frac{1}{2}$-4 months after the creation of the heart lesion, they appeared suddenly 50-70 seconds after the beginning of the adrenalin bradycardia and lasted from 35 to 55 seconds. The left ventricular rhythm during the attacks was over 200 beats per minute (204, 210, 214). The attacks ceased just as suddenly as they began. In the few seconds immediately before the attack began or after it ended, isolated left ventricular extrasystoles were observed (Fig. 1, a-c).

An essential feature was that in our experiments the attacks of paroxysmal tachycardia arose, not episodically as in the majority of experimental investigations previously published [2, 3 and others], but in a form regularly reproducible from one experiment to the next.

According to the most reliable view of the common origin of extrasystoles and paroxysmal tachycardia, the main rola in the mechanism of these phenomena is played by the appearance in the myocardium of a focus of heterotopic excitation, which, under suitable conditions (a lowering of the automatism of the sinus node, an increase in the excitation of the myocardium and so on), temporarily becomes the pacemaker of the cardiac rhythm. In this connection it was important to determine whether or not signs of cardiosclerosis developed in the muscle of the hypertrophied left ventricle of the dogs with experimental aortic stenosis, since areas of myocardium situated in the immediate proximity of cardiosclerotic foci may act as sources of heteropic excitation in paroxysmal tachycardia.

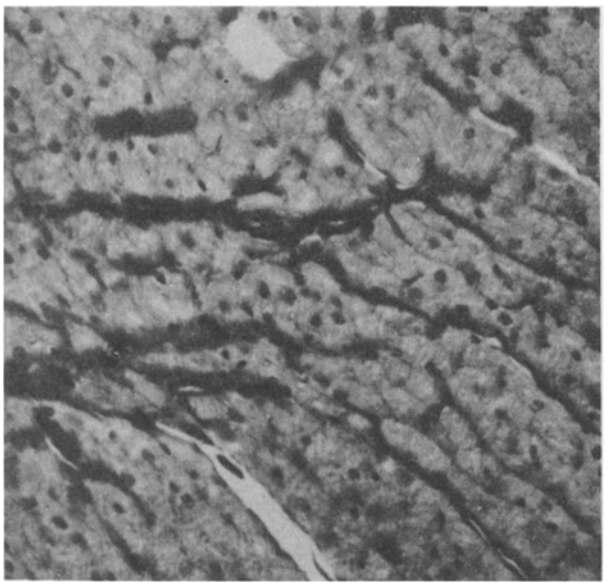

Fig. 2. Marked cardiosclerosis in the myocardium of the left ventricle of a dog with an experimental heart lesion. Thick bands of collagen fibers are seen, situated between the muscle bundles.

The subsequent morphological examination of the hearts of the dogs with aortic stenosis, in which attacks of paroxysmal tachycardia were observed, showed that hypertrophy of the left ventricle in these animals was combined with the development of a well-marked cardiosclerosis. On investigation of the heart of the dog Pushok, for example, 8 months after the creation of the lesion, the findings were as follows: absolute weight of the heart—201 g, relative weight of the heart— 0.0011, i.e., 55-60 % greater than normally.

On histological examination of the heart, hypertrophy of the muscle fibers was found, mainly in the wall of the left ventricle. There was predominance of thickened muscle fibers with large, light, elongated nuclei. The borders between the muscle fibers were ill-defined. Alongside the hypertrophied fibers, thinned, atrophic muscle fibers with small hyperchromic nuclei were seen. On staining with picrofuchsin, well-marked cardiosclerosis was found, in the form of proliferation of thick collagen fibers between the muscle bundles (Fig. 2). Perivascular sclerosis with thickening of the tunica media of the arteries and the development in it of collagen fibers were found. Basically similar results were obtained on examination of the hearts of the other animals.

Thus in the dogs with experimental aortic stenosis, side by side with hypertrophy of the myocardium was observed the development of cardiosclerosis, and against a background of adrenalin-induced bradycardia arose attacks of paroxysmal tachycardia.

When regarding the areas of myocardium stimulated by the cardiosclerotic process as potential sources of heterotopic excitation, it must be supposed that during adrenalin-induced bradycardia, on account of reflex inhibition of the automatism of the sinus node, and also as the result of the direct excitatory action of adrenalin on cardiac muscle, these potential sources of heterotopic rhythm in the myocardium of the left ventricle become its real sources — an attack of paroxysmal tachycardia then supervenes.

Situations in which, against a background of some degree of cardiosclerosis, there is a simultaneous lowering of the automatism of the sinus node and an increase in the excitation of the myocardium are evidently also possible in clinical practice, for a rise in the blood adrenalin is frequently observed in man and is an indispensible component of states such as anger, fear, pain and physicial strain. It is very probable that these cortically induced states, arising against a background of cardiosclerosis, from time to time provoke the onset of attacks of paroxysmal tachycardia or extrasystoles in man.

SUMMARY

Extrasystoles were observed in normal dogs against the background of reflex bradycardia caused by the intravenous administration of adrenalin. Three - four months after the creation of experimental aortic stenosis attacks of left ventricular paroxysmal tachycardia appeared in the same animals after the administration of the same dose of adrenalin. Three factors play an important role in the appearance of these attacks: 1) vagal inhibition of the automatism of the sinoatrial node; 2) direct action of adrenalin, increasing the myocardial excitability; 3) stimulating effects of cardiosclerotic foci on definite areas of the left ventricular myocardium.

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